

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

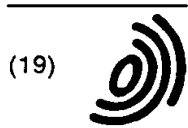
Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 0 953 728 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.11.1999 Bulletin 1999/44

(51) Int Cl.⁶: **F01D 5/14, F04D 29/68**

(21) Application number: **99303217.6**

(22) Date of filing: **26.04.1999**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**
Designated Extension States:
AL LT LV MK RO SI

(72) Inventors:
• Hashimoto, Keisuke
Kobe-shi, Hyogo 651-2274 (JP)
• Suga, Shinya
Kobe-shi, Hyogo 651-2272 (JP)
• Sakai, Yusuke
Kobe-shi, Hyogo 655-0885 (JP)

(30) Priority: **27.04.1998 JP 13440198**

(71) Applicant: **Kawasaki Jukogyo Kabushiki Kaisha**
Kobe-shi, Hyogo 650-8670 (JP)

(74) Representative: **Abbie, Andrew Kenneth et al**
R.G.C. Jenkins & Co.
26 Caxton Street
London SW1H 0RJ (GB)

(54) **Booster compressor with tandem blading**

(57) To provide a booster structure capable of obtaining a desired pressure ratio with fewer stages. The

moving blade of a booster 2 is a boundary layer control tandem moving blade 11.

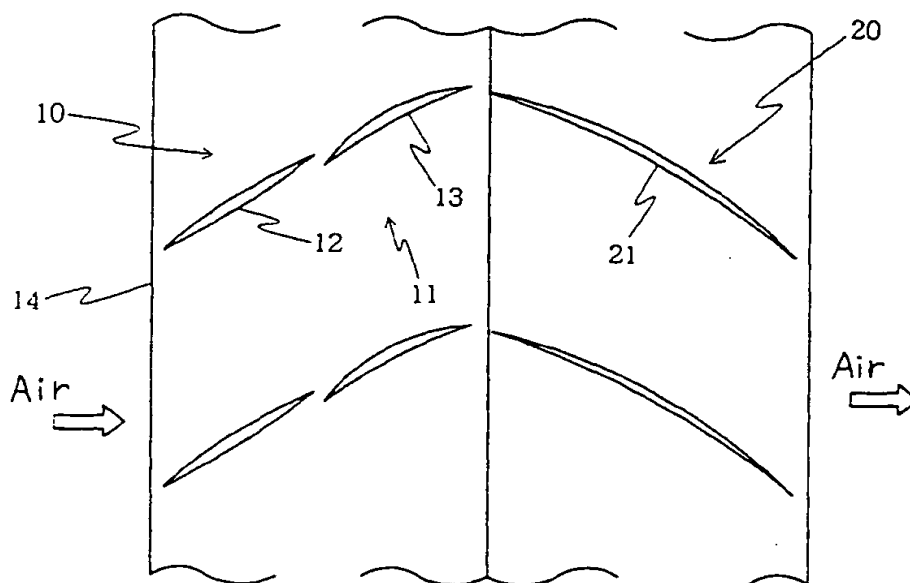


Fig. 2

Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

[0001] The present invention relates to the booster structure of a jet engine. More specifically, the present invention relates to a jet engine booster structure having a pressure ratio in a single stage improved.

10 **Description of the Related Art**

[0002] In the prior art, there has been provided a booster 2' in the downstream of a fan 1 in order to enhance the performance of a high bypass engine, as shown in FIG. 11.

15 [0003] As shown in FIG. 11, however, the booster 2' is provided at the same shaft 3' as the fan 1 and the number of revolution of the booster 2' is the same as that of the fan 1, whereby the circumferential speed of the moving blade 4 of the booster 2' is, therefore, limited by that of the fan 1. Due to this, the circumferential speed of the moving blade 4 is extremely lower than a desired speed, so that a pressure ratio in a single stage becomes quite low. This results in a problem that the booster 2' must consist of many stages so as to ensure a desired pressure ratio. Also, if the number of stages of the booster 2' increases, the entire length of a compressor increases, resulting in a problem that the weight of an engine E' increases. Furthermore, an increase in weight causes various problems.

SUMMARY OF THE INVENTION

25 [0004] The present invention has been made in view of the problems according to the prior art and has an object to provide a booster structure capable of obtaining a desired pressure ratio with fewer stages.

[0005] The jet engine booster structure according to the present invention is characterized in that a moving blade of a booster is a boundary layer control tandem moving blade.

30 [0006] In the jet engine booster structure according to the present invention, it is preferable that the inflow angle with a tandem moving blade lattice is within a range of 50 degrees to 70 degrees and that the efflux angle from the tandem moving blade lattice is within a range of 0 degree to 45 degrees. In addition, it is preferable that the deflection angle by a stator blade is within a range of 0 degree to 45 degrees.

[0007] Since the moving blade of the booster is the tandem moving blade in the booster structure according to the present invention, a pressure increase in a single stage is large and, therefore, a desired pressure increase can be attained with fewer stages.

35 [0008] Now, description will be given based on the mode of working the present invention with reference to the accompanying drawings. The present invention should, however, not be limited to the mode.

BRIEF DESCRIPTION OF THE DRAWINGS

40 [0009] FIG. 1 is a schematic view of a turbo fan engine provided with a booster structure in one mode of embodiment according to the present invention.

[0010] FIG. 2 is a schematic view of the important parts of the booster structure in one mode of embodiment according to the present invention.

[0011] FIG. 3 is a typical view of a flow of the tandem moving blade used in the mode of embodiment.

45 [0012] FIG. 3 is an explanatory view showing velocity triangles in a tandem moving blade lattice and a stator blade lattice used in the mode of embodiment.

[0013] FIG. 5 is a side view of one example of the tandem moving blade lattice.

[0014] FIG. 6 is a cross-sectional view showing a HUB section of the tandem moving blade lattice in FIG. 5.

[0015] FIG. 7 is a cross-sectional view showing a MEAN section of the tandem moving blade lattice in FIG. 5.

50 [0016] FIG. 8 is a cross-sectional view showing a TIP section of the tandem moving blade lattice shown in FIG. 5.

[0017] FIG. 9 is a schematic view of a testing device used for a performance test of the embodiment and a comparative example.

[0018] FIG. 10 is an explanatory view showing a measurement method in the testing device shown in FIG. 9.

55 [0019] FIG. 11 is a schematic view of a turbo fan engine provided with a conventional booster structure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] A turbo fan engine E having a jet engine booster structure in mode 1 of working the present invention is shown

in FIG. 1 and the important parts thereof are shown in FIG. 2 schematically. In the booster structure, the moving blade of a booster 2 is a tandem moving blade 11. The tandem moving blade 11 is specifically a boundary layer control tandem moving blade 11. In other words, the moving blade lattice of this booster 2 is a tandem moving blade lattice 10.

[0021] The shapes of the front blade 11 and rear blade 12 of the tandem moving blade 11 in this tandem moving blade lattice 10, the positional relationship between the front blade 12 and the rear blade 13, the positional relationship between the tandem moving blade lattice 10 and a stator blade lattice 20, pitches of the tandem moving blade lattice 10 and stator blade lattice 20 and the like are determined by performing three-dimensional calculation fluid dynamics using a computer. As for the tandem moving blade lattice 10, for instance, as typically shown in FIG. 3, the speed, momentum and the like of a jet spouted from the trailing edge of the lower surface of the front blade 12 onto the upper surface of the rear blade 13 are regulated, thereby causing the jet to flow along the upper surface of the rear blade 13. As a result, separation of a boundary layer on the upper surface of the rear blade 13 is set to be restricted to the vicinity of the trailing edge of the rear blade 13. In other words, the boundary layer of the rear blade 13 is controlled by the front blade 12. Reference symbol 3 in the figure denotes a shaft which drives the fan 1 and the booster 2, reference symbol 14 denotes a disk and reference symbol 21 denotes a stator blade.

[0022] Any program for three-dimensionally analyzing a flow around the blade lattice and the distribution of a shock wave can be used, and an application program thereof is not particularly restricted.

[0023] In addition, the shape of the stator blade lattice 20 is preferably set such that the inflow angle (with the tandem moving blade lattice 10 shown in FIG. 4 is within a range of 50 to 70 degrees. Also, the shapes of the front blade 12 and rear blade 13 of the tandem moving blade lattice 10 are preferably set such that the efflux angle (from the tandem moving blade lattice 10 in this case is within a range of 0 to 45 degrees. Further, the deflection angle by the stator blade 21 is preferably within a range of 0 to 45 degrees.

[0024] Thus, the tandem moving blade lattice 10 having the above characteristics can be obtained by setting the positional relationship between the front blade 12 and the rear blade 13 of the tandem moving blade 11 and that of the tandems 11 and 11 or, for instance, the dimensional relationship between the front blade 12 and the rear blade 13 as shown in FIGS. 5 through 8, by changing the mutual relationship between the front blade 12 and the rear blade 13 from a state in which the front blade 12 and the rear blade 13 are laid down together from an HUB section to a TIP section to a state in which they rise together, and by gradually increasing the gap between the front blade and the rear blade 13. In other words, if the front blade 12 and the rear blade 13 are twisted together, the tandem moving blade lattice 10 having the above characteristics can be obtained.

[0025] As stated above, in this mode of embodiment, the tandem moving blade lattice 10 is used for the moving blade of the booster 2 and a pressure ratio in a single stage is, therefore, high. Thus, the number of stages of the booster 2 can be reduced, with the result that the dimensions of a compression mechanism structure can be decreased and the weight thereof can be reduced, as well.

[0026] It is noted that the tandem moving blade 11 having a characteristics that the boundary layer of the rear blade 13 is controlled by the front blade 12 is defined as "boundary layer control tandem moving blade" in the present specification.

[0027] Now, the present invention will be described more specifically based on a more specific embodiment.

Embodiment and Comparative Example:

[0028] A boundary layer control tandem moving blade lattice (embodiment) having principal items shown in Table 1 was fabricated with a shape of and a dimension shown in FIGS. 5 through 8, which tandem moving blade lattice served as a booster. The performance of this booster was measured by a testing device shown in FIG. 9. In addition, a conventional blade lattice (comparative example) having principal items shown in Table 2 was fabricated with the same width as that of the tandem moving blade according to the embodiment, and the performance thereof was measured by the same testing device in the embodiment.

[0029] As typically shown in FIG. 10, measurement was performed by disposing a total pressure measuring probe and a total temperature measuring probe in front and rear portions of the blade (points A and B in FIG. 10) respectively, and radially traversing the probes every millimeter between TIP and HUB section. An flow rate was measured by an orifice provided in the upstream of an inlet duct section. The number of revolutions of the blade lattice was measured by a revolution measuring pick-up provided on a rotation shaft of a disk to which the blade lattice is attached.

[0030] Each data obtained by the measurement was processed in the following manner.

(1) Each of average measured values of a total pressure and a total temperature between the TIP and HUB sections on the portions A and B is calculated.

(2) A pressure ratio is calculated based on a ratio PB/PA of an average value PB of the total pressure on the point B to an average value PA of the total pressure on the point A.

(3) An average value TB of the total temperature on the point B and an average value TA of the total temperature

on the point A are also calculated, and the average value PB of the total pressure on the point B and the average value PA of the total pressure on the point A which have been calculated are also used to obtain an efficiency by the following equation.

$$\eta = TA \{ (PB/PA)^{(k-1)/k} - 1 \} / (TB - TA)$$

where η is Adiabatic efficiency and k is Adiabatic exponent.

[0031] Table 1 shows the result of measurement in the embodiment, and the pressure ratio, pressure increase and the adiabatic efficiency thus calculated together with principal items of the embodiment. Table 2 shows a result of measurement, the pressure ratio, the pressure increase and the efficiency in the comparative example.

[Table 1]

Embodiment	Principal Item	Measured value
Number of blades	Front blade 24	-----
	Rear blade 24	
Diameter of blade tip (mm)	265	-----
Number of revolutions (rpm)	16023	16000
Flow rate (kg/s)	-----	3.25
Pressure ratio	-----	1.3
Pressure increase	-----	0.3
Adiabatic Efficiency (%)	-----	87

[Table 2]

Comparative Example	Principal Item	Measured value
Number of blades	24	-----
Diameter of blade tip (mm)	265	-----
Number of revolutions (rpm)	16023	16000
Flow rate (kg/s)	-----	3.25
Pressure ratio	-----	1.15
Pressure increase	-----	0.15
Adiabatic efficiency (%)	-----	86.5

[0032] It is apparent from a comparison between Table 1 and Table 2 that a high pressure ratio of 0.3 which is about 2.0 times as high as that of the comparative example can be obtained in the embodiment while keeping the same efficiency as in the comparative example.

[0033] Although the present invention has fully been described based on the mode of working the invention and

embodiment, it is to be understood that the present invention should not be limited thereto and various changes and modifications are possible. For instance, while the tandem moving blade lattice has a single stage in the mode of working the invention as well as the embodiment, the number of stages can be two or three in accordance with a required pressure ratio.

[0034] As staged so far in detail, in the booster structure of the present invention, the booster moving blade is a tandem moving blade. Due to this, the structure has excellent advantage in that a pressure increase in a single stage is larger and that a desired pressure increase can be attained with fewer stages. Besides, since the booster is allowed to have fewer stages, the present invention exhibits excellent advantage in that the entire length of the compressor can become smaller and the weight thereof can be reduced.

Claims

1. A jet engine booster structure characterised in that a moving blade of a booster is a boundary layer control tandem moving blade.
2. The jet engine booster structure according to claim 1, characterised in that an inflow angle with a tandem moving blade lattice is within a range of 50 degrees to 70 degrees.
3. The jet engine booster structure according to claim 1, characterised in that an efflux angle from a tandem moving blade lattice is within a range of 0 degree to 45 degrees.
4. The jet engine booster structure according to claim 1, characterised in that a deflection angle by a stator blade is within a range of 0 degree to 45 degrees.
5. A jet engine characterised by comprising a booster structure according to claims 1 through 4.
6. A compressor (2) for a jet engine (E), the compressor (2) having at least one stage comprising a rotor blade means (11) arranged in sequence with a stator blade (21), the rotor blade means (11) comprising two rotor blades (12, 13) in a predetermined fixed relationship.
7. A jet engine (E) comprising the compressor (2) as claimed in claim 6.

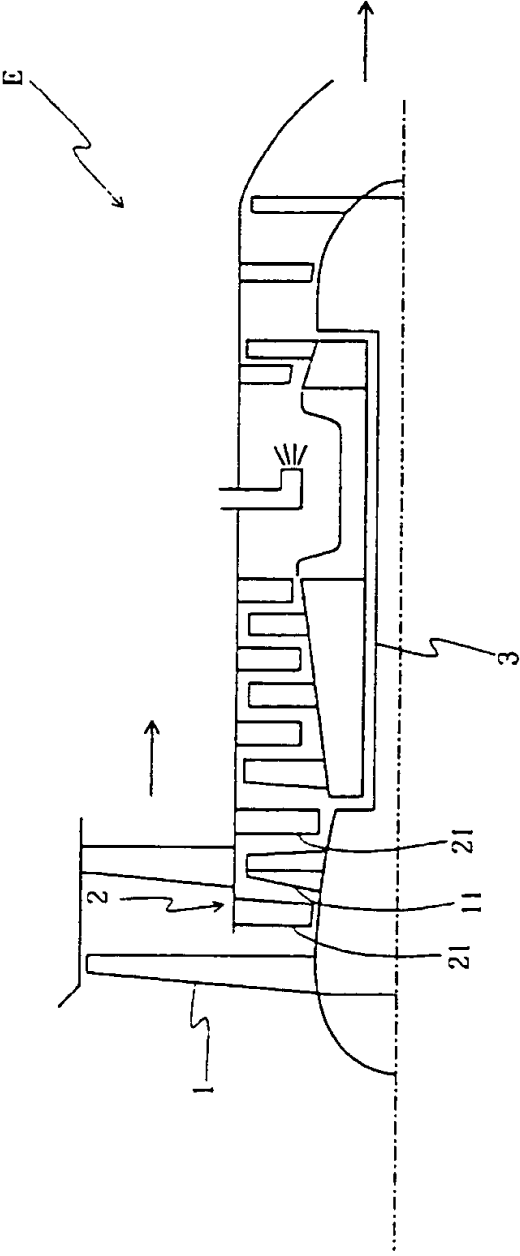


Fig. 1

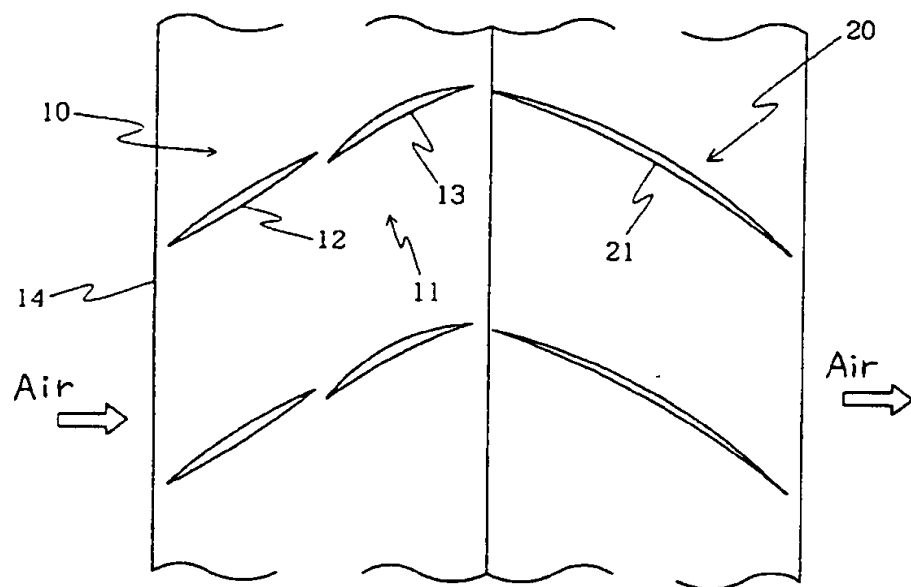


Fig. 2

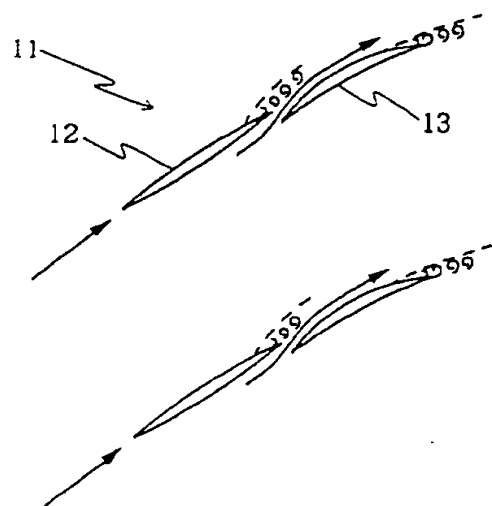


Fig. 3

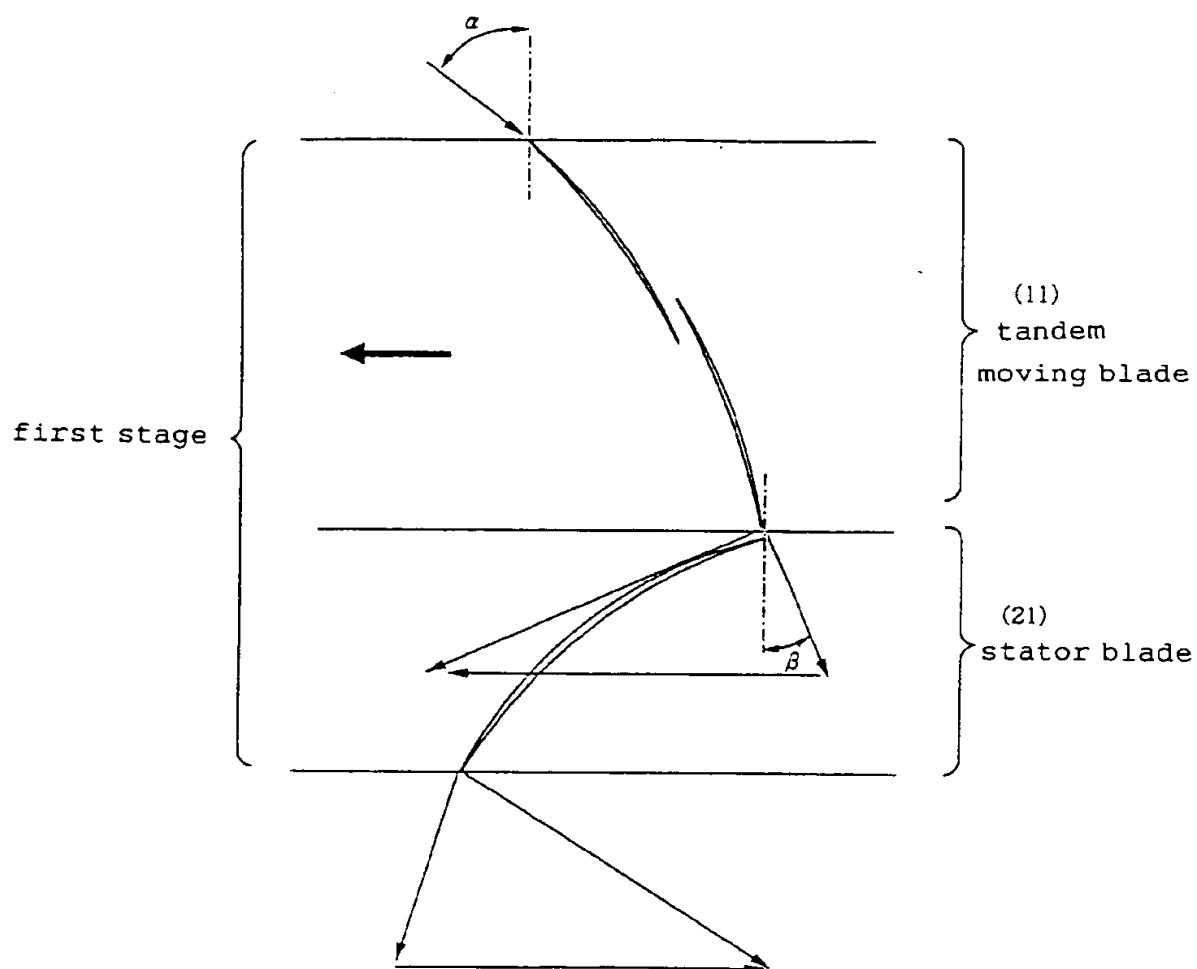


Fig. 4

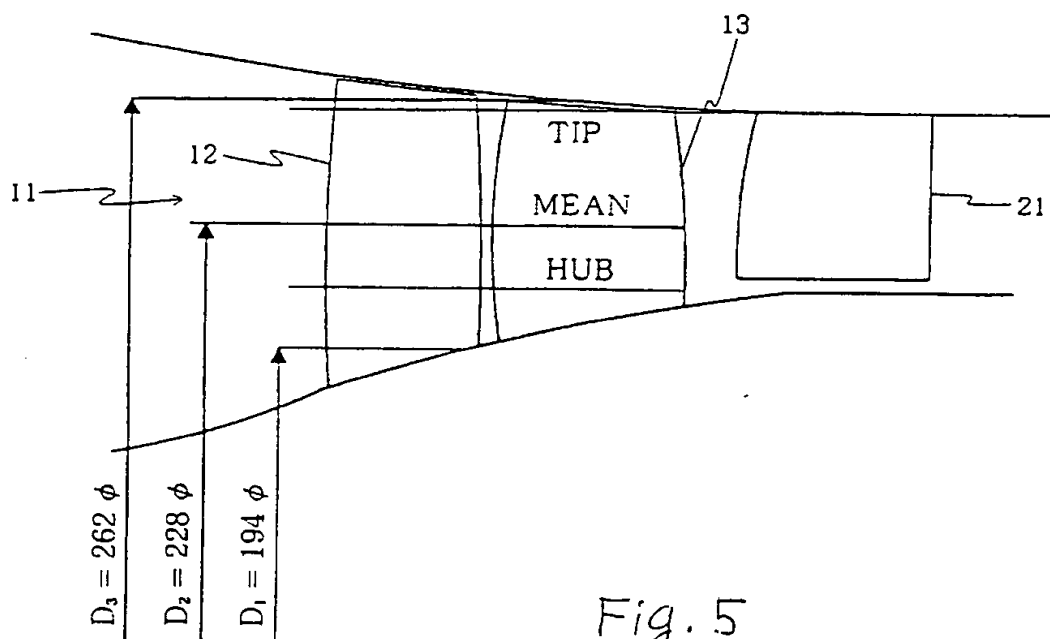
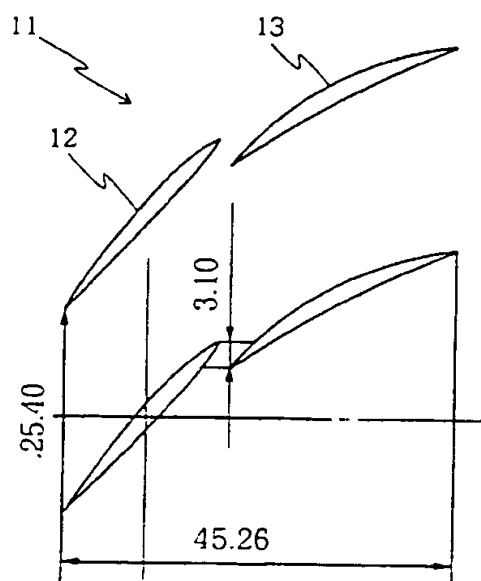
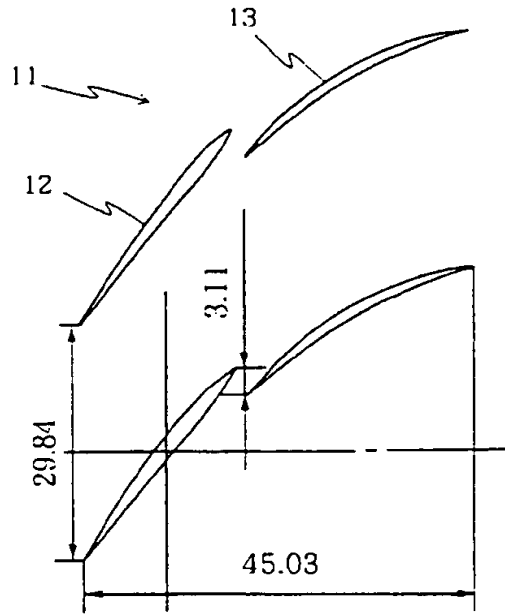


Fig. 5

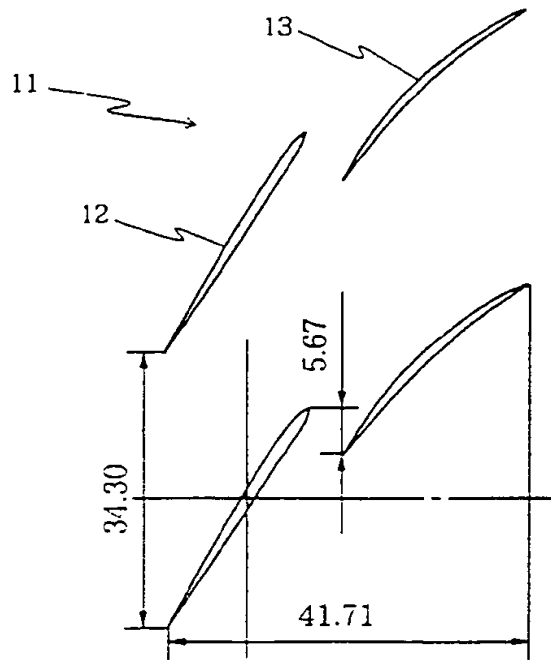


10

Fig. 6



10



10

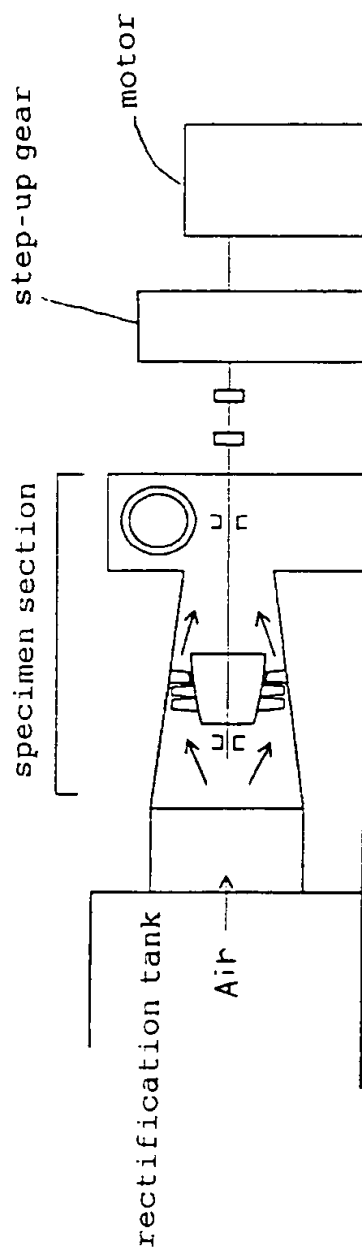


Fig. 9

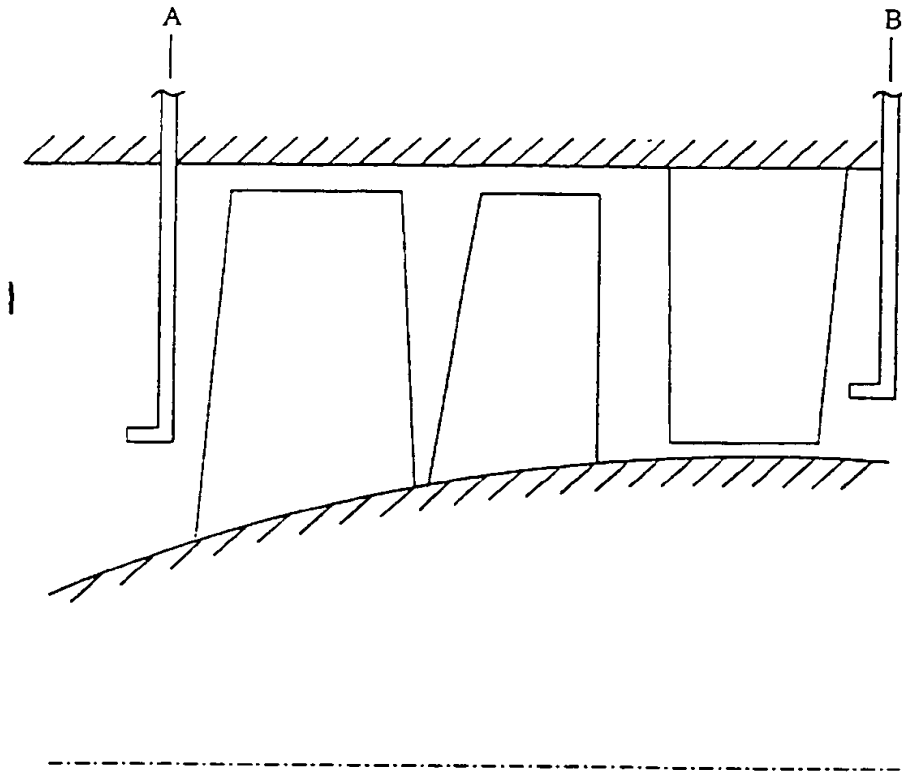


Fig. 10

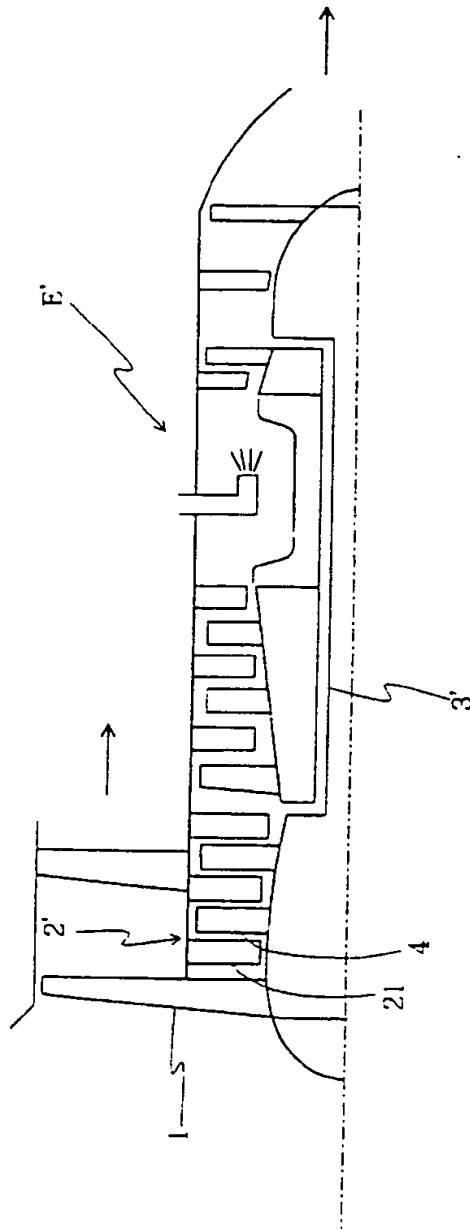


Fig. 11



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 3217

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.8)
X	US 3 937 592 A (BAMMERT KARL) 10 February 1976 (1976-02-10)	1	F01D5/14 F04D29/68
Y	* the whole document *	2-7	
X	EP 0 823 540 A (KAWASAKI HEAVY IND LTD) 11 February 1998 (1998-02-11)	1	
Y	* abstract; figures 1,2,5,6 *	2-7	
X	DE 573 799 C (LANGHANS) 5 April 1933 (1933-04-05)	1	
Y	* the whole document *	2-4	
X	US 3 112 866 A (FORTESCUE) 3 December 1963 (1963-12-03)	1	
	* column 2, line 54 - line 59; figure 2 *		
A	DE 39 24 829 A (MOTOREN TURBINEN UNION) 7 February 1991 (1991-02-07)	1-7	
	* abstract; figures 1,2 *		
			TECHNICAL FIELDS SEARCHED (Int.Cl.8)
			F01D F04D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 9 September 1999	Examiner Iverus, D
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons S : member of the same patent family, corresponding document X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 99 30 3217

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-09-1999

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3937592	A	10-02-1976	NONE	
EP 0823540	A	11-02-1998	JP 10054301 A	24-02-1998
			CA 2208113 A	09-02-1998
DE 573799	C		NONE	
US 3112866	A	03-12-1963	NONE	
DE 3924829	A	07-02-1991	FR 2650338 A	01-02-1991
			GB 2235734 A,B	13-03-1991
			IT 1242978 B	18-05-1994

EPO FORM 100/99

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82